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ABSTRACT

A substantially revised Medical College Admission Test (MCAT) was introduced in spring 1991. The new examination is designed to assess critical thinking skills, basic concepts and problem solving facility in science, and writing skills. This paper reports preliminary findings on the factor structure of the revised MCAT, which consists of four sections: Verbal Reasoning, Physical Sciences, Writing Sample, and Biological Sciences. It was found that a four-factor solution was appropriate for three samples (6,776 students, 1,699 students, and 2,336 students, respectively) selected from three forms (Forms 952, 773, and 105, respectively) administered in spring 1991. A verbal reasoning factor and a writing factor were clearly defined in all analyses. A physics/chemistry factor and a biology factor were found for the total group, White group, and males. A general science factor was found for females, Asians, and Blacks. Factor correlations were compared to correlations between approximately comparable reported scores, and patterns were consistent. Results suggest that the verbal reasoning and writing sample sections have the anticipated internal structures. Because organic chemistry variables load with variables from the physical sciences section rather than the biological sciences section, science variables bear further examination. Additional research on the construct validity of the MCAT is planned. Seven tables present study data. (Author/SLD)

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Preliminary Investigation of the 1991 Medical College Admission Test Factor Structure

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Association of American Medical Colleges

Presented at the Annual Meeting of
the American Educational Research Association

San Francisco
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Abstract

A substantially revised Medical College Admission Test was introduced in spring 1991. The new exam is designed to assess critical thinking skills, basic concepts and problem solving facility in science, and writing skills. It consists of four sections: Verbal Reasoning, Physical Sciences, a Writing Sample, and Biological Sciences. This paper reports preliminary findings on the factor structure of the revised MCAT.

It was found that a 4-factor solution was appropriate for all three samples selected from three different forms administered in spring 1991. A verbal reasoning factor and a writing factor were clearly defined in all analyses. A physics/chemistry factor and a biology factor were found for the total group, white group, and male group. A general science factor was found for the female, Asian, and black groups. Factor correlations were compared to correlations between approximately comparable reported scores, and patterns were consistent.

The reported results suggest that the Verbal Reasoning and Writing Sample sections have the anticipated internal structures. The organic chemistry variables load with variables from the Physical Sciences section rather than the Biological Sciences section. The science variables bear further examination. Additional research on the construct validity of the 1991 MCAT is planned.

Key words: test, construct validity, MCAT

The Association of American Medical Colleges introduced a new version of the Medical College Admission Test (MCAT) in April 1991 (AAMC, 1989). This revised MCAT was a result of multi-year research and development effort (Swanson & Mitchell, 1989). The revised MCAT is designed to help medical schools identify desirable physician candidates. The specifications for the new MCAT call for an assessment of mastery of basic concepts in introductory science courses; facility at science problem solving and critical thinking; and communication/writing skills. This study analyzes national data from the first administration of the updated MCAT in spring 1991. The objective of this research is investigation of the new MCAT factor structure. This study will provide early feedback to the test development process and MCAT score reporting procedures. Further studies on the construct validity of the exam will build upon results of this study.

Introduction

The 1991 MCAT has four sections: Verbal Reasoning (VR), Physical Sciences (PS), Biological Sciences (BS), and Writing Sample (WS). The Verbal Reasoning section focuses on reading comprehension, critical thinking, and logical reasoning skills. Each group of 6-10 test items is based on a text passage with 500-600 words from the humanities, social sciences, and natural sciences. Expertise in these disciplines is not evaluated. It is hoped that inclusion of these materials on the new test will encourage baccalaureate students interested in a medical career to investigate the varieties of human experience available through broad study in the humanities, social and natural sciences.

Each item in the VR section is classified into one of four cognitive skill categories:

Comprehension. These items test the ability to recognize key information or concepts contained in the passage text.

Evaluation. These items ask the examinee to consider the accuracy, consistency, or reliability of information or arguments presented in the passage.

Application. These items require the examinees to solve, on the basis of their understanding of the passage, a problem or interpret a hypothetical situation beyond the immediate scope of the passage.

Incorporation of New Information. These items ask the examinees to reevaluate the content of the passage in light of new information presented in the question.

The Physical Sciences section assesses knowledge of basic concepts in general chemistry and physics through their application to the solution of specific science problems. It presents a series of problems describing situations upon which multiple choice questions are

constructed. Usually a passage has about 250 words and is followed by 4-8 questions. Interpretation of tabular and graphic information is also assessed by the science sections.

Each passage in the Physical Sciences section can be classified into one of four categories: information presentation, problem solving, research studies, and persuasive argument. In addition to these passage formats, a small number of stand-alone items are presented to cover certain content areas that do not lend themselves to the passage format.

It is likely that some of the reasoning skills assessed by the Verbal Reasoning section will overlap with the problem solving skills evaluated through the science sections. Thus, one of the objectives of this study is to explore the extent to which skills in Verbal Reasoning relate to science problem solving skills.

Another MCAT science section is the Biological Sciences section. The format, number of questions, distribution of item types, and cognitive skill classifications are parallel to the Physical Sciences section. The Biological Sciences section covers basic concepts in biology and organic chemistry. This arrangement is a result of several goals for the recent MCAT revision. First, it was felt that the revised MCAT should reduce the number of science test sections in order to reduce examinees' testing burden and to encourage pre-medical students to pursue a balanced undergraduate education rather than narrowly focusing on the sciences. This objective ruled out the possibility of designing separate sections for each of physics, biology, and chemistry. Second, medical school representatives indicated that chemistry content should have a greater weight in the new test since it had a greater predictive value. Third, studies of the estimated predictive value of a new test battery were completed in preparation for revising the MCAT; these studies indicated that combining organic chemistry with biology and combining physics with general chemistry would not adversely reduce the predictive value of the test.

In the Writing Sample section, examinees are asked to write two 30-minute essays responding to specific questions regarding a given quotation. Reported scores reflect students' abilities to develop a central idea, synthesize concepts and ideas, present ideas cohesively and logically, and write clearly and within the rules of good writing consistent with timed, first-draft composition. Inclusion of the essay section allows medical school candidates to demonstrate their analytic and writing skills beyond the opportunity provided by the medical school application form.

Unlike the VR, PS, and BS multiple-choice items which are scored dichotomously, each of an examinee's two essays is scored on a scale ranging from 1 to 6. Each of the two essays

are scored by at least two readers[1]. An examinee's reported score on the Writing Sample section is the scaled score conversion of the sum of four individual ratings.

Methods

At the spring 1991 administration, three parallel forms were administered to 22,383 examinees. The first sample of 6776 examinees was selected from Form 952. It included 2788 (41%) females, 3988 (59%) males, 384 (6%) blacks, 4830 (71%) whites, 1162 (17%) Asians, and 400 (6%) others. The second sample (Form 773, N = 1699) and the third sample (Form 105, N = 2336) were selected under comparable conditions; for example, examinees in the three samples took the test on the same day. Group breakdowns for the three samples are very similar, and the breakdowns are very close to those of the population. For example, the entire spring 1991 MCAT examinee population included 41% females, 71% whites, and 6% blacks.

The analyses for the three samples were handled simultaneously and under identical procedures. Therefore, the following discussion for one sample applies equally to the other two samples. In the Verbal Reasoning section, dichotomously scored items associated with the same passage were summed together to create eight observed variables. An examinee received a score of 1 if the item was correctly answered. If the answer to the question is incorrect or missing, the examinee received a 0. Speededness is not a concern with MCAT; therefore missing an item or answering a question incorrectly were not distinguished in the analysis.

In the science sections, a similar method was employed to combine the majority of items; as earlier stated that most science items are presented in a problem format. The remaining stand-alone items were summed together according to their content classifications. For example, all general chemistry items in a discrete format were summed together to create a variable within the Physical Sciences section; all physics items in a discrete format were summed together to create another variable within the Physical Sciences section. The discrete items in Biological Sciences were summed analogously. Thus, 11 Physical Sciences variables and 11 Biological Sciences variables were created for each test form.

As stated earlier, the Writing Sample section asks an examinee write two essays, each of which is rated by two raters. Thus, there were four writing scores to be considered in this analysis. The first two scores came from two independent raters for the first essay, and the last two scores came from two independent raters for the second essay. Unlike creating

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[1]If the two ratings on a paper are more than one score point apart, a third, more experienced rater is brought in to review the paper and assign a final score. In spring 1991 administration, fewer than .5% papers required a third review. Therefore, the third score was not considered in this study.

variables for the multiple-choice sections, there was no need to combine the four writing scores before any analysis, because each writing score already ranged from 1 to 6.

A principal axis factor procedure, whereby communality estimates replaced the correlation matrix diagonals during factor extraction, was used in all the analyses reported in this paper. An oblique rotation was applied to obtain correlations between the rotated factors.

The analyses proceeded in two steps. First, the test structures across three samples were examined. Next, group-specific analyses were conducted on the first sample (N = 6776). Due to sample size limitations, test structure was examined for five groups: female, male, black, Asians, and whites.

Results

Tables 1a, 1b, and 1c present factor loading matrices from analyses of the first, second, and third samples. An inspection of the spree tree plots suggested a four-factor solution. Furthermore, analyses in the screening stage indicated that a fifth factor was inadequately identified and that a 3-factor solution would result in a poor interpretability. Thus a 4-factor solution was obtained for each sample. For clarity of display and ease of interpretation, cross loadings smaller than .35 are not included.

<Insert Tables 1a, 1b, 1c about here>

The factor loading patterns are readily interpretable across three samples. The first factor is exclusively defined across all samples by the eight variables created from Verbal Reasoning items. The second factor is also exclusively defined in all samples by examinees' writing scores.

The last two factors are defined by variables created from the science items. In the first two samples (Tables 1a and 1b), all physics, general chemistry, and organic chemistry variables load on the third factor; all biology variables load on the fourth factor with one exception: Biological Sciences 7 in the second sample does not load on the biology factor; instead, it loads on the physics/chemistry factor (the third factor). It is further noted that the biology factor in the second sample is not as strongly defined as in the first sample.

In the third sample (Table 1c), the third factor can still be described as a physics/chemistry factor, but the fourth factor is better described as a biology/chemistry factor. Although some significant cross loadings are observed in both science sections, the primary loadings do load on expected factors, and the secondary loadings are much weaker than the primary ones. For example, Physical Sciences 2 is a physics variable; its primarily loading (.51) on the physics/chemistry factor is much stronger than its secondary loading (.36) on the

biology/chemistry factor.

<Insert Tables 2a, 2b about here>

The factor correlations for the three samples are very similar; therefore, only the factor correlation matrix for the first sample is presented in Table 2a. Correlations between reported scores from the same form are also provided in Table 2b. These two tables show that correlations between factors are generally lower than correlations between **approximately** comparable reported scores. The word approximate is emphasized because the factors and the reported scores are different concepts. The correlations between reported scores are provided as a reference for interpreting the factor correlations. Moreover, the factor correlations might look somewhat different under confirmatory factor analysis procedures.

Table 3 reports factor analysis results for various examinee groups. Group analysis results across the three samples are very similar; therefore only results from the first sample (N=6776) are presented. As in Tables 1a, 1b, and 1c, cross loadings below .35 are not displayed; any primary loading below .35 is indicated by a "*" to facilitate effective visual inspection and interpretation.

<Insert Table 3 about here>

As with analyses on the full samples, a verbal reasoning factor and a writing factor are well defined across all groups. A third factor is defined for all groups, but its composition varies across groups. For the female, Asian, and black groups, the third factor is an omnibus science factor; for the white group and male group, however, the third factor is more similar to that seen in the full sample analyses. A fourth factor, the biology factor, is found in the white group and the male group.

<Insert Table 4 about here>

In order to achieve a better understanding of group differences on the science factors, means and standard deviations for the various examinee groups in spring 1991 MCAT are provided in Table 4. Table 4 shows that the Asian examinees have high scores on both science sections; this may explain why the general science factor is well defined for the Asian group. Inspecting the group performance data for female and black groups provides very limited information for interpreting the factor loading patterns. One observes that the black and female groups have generally lower science scores, and such performance may relate to a less well defined general science factor. There might be two reasons for the cross loadings on the verbal reasoning factor for science variables. It is possible that the problem solving skills tapped in the science sections overlap with the reasoning and thinking skills assessed by the Verbal Reasoning section. To explain the absence of significant cross loading on VR

factor from PS and BS for other groups, one might hypothesize that the overlapping cognitive skills addressed by VR and the science sections play a critical role only when the examinee group displays relatively lower performance on the sciences. Finally, the interpretation of results for black examinees is tentative, for the sample size may not be big enough to yield a reliable solution.

Discussion

These factor solutions provide empirical evidence on the construct validity of the 1991 MCAT. The 4-factor solution for the samples selected from all the three test forms administered in Spring 1991 suggests that the internal structure of the Verbal Reasoning and Writing Sample sections of MCAT is as anticipated and consistent with the score reporting procedures for MCAT. The two science factors bear further examination; the organic chemistry variables usually load with the inorganic chemistry and physics units rather than with the biology units which appear with them in the Biological Sciences section of the exam. These findings need to be replicated through analyses of additional data (e.g., fall 1991 or spring 1992 MCAT data). Moreover, the community estimates indicate that substantial measurement errors is present for some variables (e.g., VR04, VR05, PS05, PS06, PS09, PS02, PS044, BS01, & BS11) under current scheme of combining items based on perceived content/passage similarities. This study is exploratory in nature; it reports initial empirical evidence for the construct validity of the revised MCAT. It also serves as necessary preparation for subsequent confirmatory factor analyses currently in progress. Test development and score reporting modifications will not be contemplated in the absence of further study.

References

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Table 1a Factor Loading Matrix for 1991 MCAT
(Sample One, N=6776)

Observed Variable	Factor 1	Factor 2	Factor 3	Factor 4
Verbal Reasoning 7	.66			
Verbal Reasoning 8	.62			
Verbal Reasoning 1	.60			
Verbal Reasoning 6	.60			
Verbal Reasoning 5	.52			
Verbal Reasoning 2	.51			
Verbal Reasoning 3	.50			
Verbal Reasoning 4	.46			
Writing 3		.67		
Writing 4		.65		
Writing 2		.64		
Writing 1		.62		
Physical Sciences 10			.62	
Physical Sciences 7			.59	
Physical Sciences 8			.55	
Physical Sciences 11			.55	
Physical Sciences 9			.47	
Physical Sciences 3			.44	
Physical Sciences 1			.41	
Physical Sciences 5			.36	
Physical Sciences 6			.34	
Physical Sciences 4			.23	
Physical Sciences 2			.21	
Biological Sciences 4			.61	
Biological Sciences 9			.50	
Biological Sciences 7			.40	
Biological Sciences 10			.37	
Biological Sciences 3				.55
Biological Sciences 2				.52
Biological Sciences 5				.51
Biological Sciences 8				.48
Biological Sciences 11				.48
Biological Sciences 6				.40
Biological Sciences 1				.33

Table 1b Factor Loading Matrix for 1991 MCAT
(Sample Two, N=1699)

Observed Variable	Factor 1	Factor 2	Factor 3	Factor 4
Verbal Reasoning 7	.73			
Verbal Reasoning 6	.63			
Verbal Reasoning 4	.60			
Verbal Reasoning 5	.59			
Verbal Reasoning 2	.58			
Verbal Reasoning 8	.56			
Verbal Reasoning 3	.55			
Verbal Reasoning 1	.53			
Writing 2		.68		
Writing 1		.67		
Writing 3		.63		
Writing 4		.62		
Physical Sciences 11			.68	
Physical Sciences 4			.61	
Physical Sciences 1			.55	
Physical Sciences 9			.53	
Physical Sciences 8			.48	
Physical Sciences 7			.45	
Physical Sciences 10			.40	
Physical Sciences 2			.41	
Physical Sciences 5			.40	
Physical Sciences 6			.38	
Physical Sciences 3			.35	
Biological Sciences 8			.59	
Biological Sciences 3			.58	
Biological Sciences 6			.52	
Biological Sciences 7			.31	
Biological Sciences 10			.43	.34
Biological Sciences 11				.45
Biological Sciences 1				.32
Biological Sciences 4				.32
Biological Sciences 2				.30
Biological Sciences 5				.29
Biological Sciences 9				.24

Table 1c Factor Loading Matrix for 1991 MCAT
(Sample Three, N=2336)

Observed Variable	Factor 1	Factor 2	Factor 3	Factor 4
Verbal Reasoning 7	.67			
Verbal Reasoning 4	.65			
Verbal Reasoning 8	.65			
Verbal Reasoning 6	.64			
Verbal Reasoning 5	.61			
Verbal Reasoning 1	.58			
Verbal Reasoning 3	.55			
Verbal Reasoning 2	.53			
Writing 3		.75		
Writing 4		.74		
Writing 2		.70		
Writing 1		.67		
Physical Sciences 11			.63	
Physical Sciences 7			.62	
Physical Sciences 9			.58	
Physical Sciences 5			.55	
Physical Sciences 10			.55	
Physical Sciences 6			.54	
Physical Sciences 8			.48	
Physical Sciences 1			.52	.36
Physical Sciences 2			.51	.36
Physical Sciences 3			.50	.38
Physical Sciences 4				.34
Biological Sciences 5			.48	
Biological Sciences 3			.47	
Biological Sciences 2			.37	.54
Biological Sciences 8				.64
Biological Sciences 1				.57
Biological Sciences 7				.52
Biological Sciences 10				.51
Biological Sciences 9				.49
Biological Sciences 6				.47
Biological Sciences 11				.43
Biological Sciences 4				.41

Table 2a 1991 MCAT Factor Correlations (Sample One, N=6776)

	Factor 1 VerbReas	Factor 2 Writing	Factor 3 Phy/Chem	Factor 4 Biology
Factor 1 (VerbReas)	1.00			
Factor 2 (Writing)	.49	1.00		
Factor 3 (Phy/Chem)	.54	.35	1.00	
Factor 4 (Biology)	.57	.25	.65	1.00

Table 2b 1991 MCAT Correlations (Above Diagonal) and Disattenuated Correlations (Below Diagonal) For Reported Scores (Form 952, April 1991)

	Verbal Reasoning	Writing Sample	Physical Sciences	Biological Sciences
Verbal Reasoning	1.00	.44	.58	.63
Writing Sample	.64	1.00	.33	.33
Physical Sciences	.70	.48	1.00	.74
Biological Sciences	.75	.47	.89	1.00

Table 3 Communality Estimates and Factor Loadings of 1991 MCAT for Gender and Ethnic Groups

Obs.	Communality Estimates					Female (N=2788)			Male (N= 3988)				Asian (N= 1162)			Black (N= 384)			White (N= 4830)				Obs.
Var.	Female	Male	Asian	Black	White	F1	F2	F3	F1	F2	F3	F4	F1	F2	F3	F1	F2	F3	F1	F2	F3	F4	Var.
VR01	.42	.44	.47	.36	.37	.67			.60				.63			.65			.55				VR01
VR02	.37	.36	.41	.24	.33	.58			.50				.59			.42			.49				VR02
VR03	.42	.36	.40	.32	.32	.63			.46				.55			.55			.45				VR03
VR04	.27	.29	.28	.22	.26	.47			.48				.50			.50			.44				VR04
VR05	.30	.29	.30	.20	.23	.55			.52				.47			.38			.48				VR05
VR06	.38	.35	.41	.32	.28	.62			.57				.56			.41			.55				VR06
VR07	.47	.51	.52	.41	.45	.68			.66				.65			.41			.61				VR07
VR08	.39	.43	.39	.32	.38	.60			.61				.54				*		.60				VR08
WS01	.44	.43	.48	.34	.40		.62			.62				.64			.59			.62			WS01
WR02	.48	.44	.50	.42	.40		.65			.63				.65			.66			.61			WR02
WR03	.37	.43	.43	.37	.38		.58			.68				.65			.56			.62			WR03
WR04	.37	.44	.45	.36	.38		.58			.66				.66			.55			.62			WR04
PS01	.28	.34	.33	.19	.29			.39			.44				.52			*			.40		PS01
PS08	.20	.37	.35	.09	.30			.43			.57				.59			*			.55		PS08
PS11	.23	.30	.27	.12	.29			.49			.53				.57			*			.53		PS11
PS03	.26	.32	.28	.24	.28			.44			.46				.48			.47			.43		PS03
PS05	.25	.30	.26	.19	.27			.39			.36				.49			.42			.36		PS05
PS07	.32	.37	.35	.26	.35			.59			.58				.61			.52			.58		PS07
PS10	.36	.43	.42	.32	.38			.61			.64				.67			.56			.60		PS10
PS06	.26	.32	.30	.15	.28			*			*				.42	*					.36		PS06
PS09	.13	.25	.20	.07	.20			*			.52				.41			*			.46		PS09
PS02	.20	.21	.21	.18	.18	*					*				*			*			*		PS02
PS04	.11	.18	.14	.09	.15	*					*				*	*					*		PS04
BS04	.36	.37	.40	.32	.34			.67			.61				.69			.60			.59		BS04
BS07	.30	.34	.39	.26	.30			.53			.42				.65			.42			.39		BS07
BS09	.29	.35	.33	.25	.32			.53			.51				.58			.53			.52		BS09
BS11	.17	.19	.19	.13	.17			.39			.38				.43			.35			.38		BS11
BS01	.20	.23	.25	.25	.16	*						*			*	.36						*	BS01
BS08	.41	.46	.46	.36	.41	.41						.46			.47	.38						.50	BS08
BS10	.33	.37	.33	.28	.34	.36						.49			.45	.35						.49	BS10
BS05	.34	.42	.40	.27	.38	.40						.50			.44			*				.52	BS05
BS03	.36	.44	.39	.31	.40	.40						.54			.44			.35				.55	BS03
BS02	.40	.41	.38	.37	.40			.39				.51			.53			.42				.55	BS02
BS06	.40	.44	.42	.30	.40			.38				.41			.48			.39				.43	BS06

* Note: Cross loadings below .35 are not displayed. Primary loadings below .35 are indicated by a *.
VR = Verbal Reasoning, WS = Writing Sample, PS = Physic Sciences, BS = Biological Sciences, F1 =Factor 1, F2 = Factor 2, etc..

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Table 4. Group Performance on Multiple Choice Sections[a] of the MCAT in Spring 1991

	Verbal Reasoning	Physical Sciences	Biological Sciences
Group	Mean/SD[b]	Mean/SD	Mean/SD
Total	8.0 (2.5)	8.0 (2.4)	8.0 (2.5)[c]
Asian	7.7 (2.5)	8.6 (2.5)	8.3 (2.5)
Male	8.0 (2.5)	8.4 (2.5)	8.3 (2.5)
White	8.3 (2.2)	8.1 (2.3)	8.2 (2.3)
Female	8.0 (2.5)	7.4 (2.2)	7.6 (2.4)
Black	5.7 (2.4)	5.8 (1.9)	5.6 (2.3)

[a] Performance on Writing Sample is reported on an 11-point alphabetic scale ranging from J to T. The medians on WS for all groups are "O".

[b] Performance on the three multiple choice sections is reported on a 1 to 15 scale.

[c] Spring 1991 examinees constitute the norming population of the revised MCAT, and the means and standard deviations were set as displayed for this population.